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Carbon Creek Spawning/rearing Channel Preliminary Design

M. R. Morgan
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Peace/Williston Fish and Wildlife Compensation Program, 1011 Fourth Ave. 3rd Floor, Prince George B.C. V2L 3H9

Website: *www.bchydro.bc.ca/environment/initiatives/pwcp/*

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Author(s): Mike R. Morgan[1]
Address(es): [1] BC Hydro, Maintenance, Engineering and Projects
6911 Southpoint Drive, Burnaby, B.C. V3N 4X8

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Peace/Williston
Fish and Wildlife Compensation Program
Carbon Creek
Spawning/Rearing Channel
Preliminary Design

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SECTION 1.0 - INTRODUCTION

1.1 PROJECT DESCRIPTION

It is proposed to develop groundwater fed spawning and rearing channels in two existing abandoned side channels of Carbon Creek. The proposed developed side channels would offer year round spawning and rearing habitat for several species of freshwater fish, including rainbow trout, kokanee, and possibly Arctic grayling and bull trout. The groundwater fed channels would be protected from flood inundation and siltation. The warmer groundwater would also prevent parts of the channels from freezing through the winter, thus providing overwintering habitat for juveniles and incubating eggs.

The project site is located approximately 40 km southwest of the Bennett Dam in the flood plain of Carbon Creek, a tributary of Williston Lake. Carbon Creek flows north into Williston Lake (Figure 1).

The site is located on the floor of a glacial valley, formed in folded sedimentary strata, near the western boundary of the Rocky Mountain Foothills. The valley slopes are veneered with a thin layer of glacial drift, between rock outcrops. The valley floor is infilled with a thick sequence of coarse fluvial and glacial fluvial deposits. A thin cover of organic soil overlays the coarse fluvial deposits in parts of the Carbon Creek flood plain. The valley floor and slopes are naturally heavily forested. The river channel has migrated and overflowed its banks in the past, leaving many abandoned side channels, some infilled with jams of large woody debris.

The proposed spawning channels are located in a clear cut block. The logged cut block is approximately 5 years old. The site is accessed by an active, well maintained logging road. The site is relatively flat and level. The surficial organic soils immediately adjacent to the proposed channel can be soft and wet. Vehicle access along the banks of the channels is limited to times of the year having minimal precipitation.

1.2 BACKGROUND

As part of the Peace/Williston Fish and Wildlife Compensation Program (PWFWCP), which is a joint effort between the B.C. Ministry of Environment (MOE) and B.C. Hydro, the development of groundwater fed spawning/rearing habitat has been proposed for two abandoned side channels of Carbon Creek.

Although the construction of groundwater fed spawning channels for freshwater fish are uncommon, similar channels for salmon have proved to be very successful.[1] Groundwater fed spawning channels are beneficial for several reasons:

- Groundwater fed channels are not subject to siltation or flooding that can destroy mainstream spawning channels.

- Groundwater fed channels are generally warmer than adjacent surface fed creeks through the winter and thus, less likely to freeze.

- Upwelling groundwater generally provides a good source of oxygen for incubating eggs.

(a) Overview Studies

Some overview work including a channel topography survey, water temperature surveys, dissolved oxygen content measurements, fish count studies, and the development of habitat criteria and proposed channel layouts have been carried out between 1991 and 1994. Brian Blackman of the PWFWCP has done the bulk of these overview studies.

(b) Feasibility Studies

In September 1994, a study to assess the feasibility of creating a groundwater fed spawning channel at the site was carried out by G. Richmond of B.C. Hydro. The feasibility study consisted of a site reconnaissance including the excavation of four test pits along the abandoned side channel.

The test pits were excavated to determine groundwater levels and the near surface soil stratigraphy. In general the stratigraphy consists of 0.5 to 1.5 meters of organic soils, silt, and sand overlying a sequence of coarse fluvial gravel, cobbles, and boulders, with some sand. The base of the coarse unit was not intercepted during the test pit program. A maximum thickness of the coarse unit excavated was 0.9 m.

A portable fire pump was used to determine the drawdown and recharge rate for each of the test pits. Based on these simple pump tests, a qualitative judgement on the available groundwater flow was made. The pits were pumped at a rate of approximately $2.3(10^{-3})$ m^3/s (30 gpm). This pumping rate resulted in a drawdown of about 5 cm in 10 minutes.

Based on the results of these pump tests it was concluded that the coarse fluvial deposits are free draining and may be able to supply significant groundwater flow to a channel excavated below the groundwater level.

The feasibility study recommended that further detailed designs be carried out to determine expected channel flow rates and to develop an optimal channel layout. The results of the feasibility study were summarized in a 27 September 1994 diary prepared by G. Richmond.[2]

Both the overview studies and feasibility assessment have shown that the development of a groundwater fed spawning and rearing channel has the potential of providing viable habitat for several species of freshwater fish.

1.3 AUTHORIZATION

Field work order J0533-691018 was issued by the Environmental Affairs Division to the Hydroelectric Engineering Division (HED) on 12 August 1994. This work order authorized HED to conduct a feasibility assessment of the proposed Carbon Creek spawning channel.

The feasibility study recommended that detailed design for the spawning channel be carried out. A new work order, J0533-690890, was issued on 13 February 1995. This work order authorizing the Soil Mechanics Department of Maintenance, Engineering, and Projects (formerly HED) to produce a preliminary design for the Carbon Creek spawning channel.

1.4 SCOPE OF WORK

The scope of the preliminary design work is as follows:

- Carry out a topographic survey of the site and develop a detailed topography plan.

- Conduct a flood study to determine the flood frequency relationship and determine the frequency of overbank flooding.

  Develop an optimal spawning/rearing channel layout which includes pool and riffle locations, stream gradients, typical cross sections and profiles, flood protection structures, and estimates of groundwater inflows.

- Estimate construction quantities, costs, and schedule.

SECTION 2.0 - TOPOGRAPHY SURVEY

A topography survey was carried out in November 1994 by Canyon Contracting of Hudson's Hope, B.C. A plan of the site was produced at a scale of 1:2000 and a contour interval of 0.5 m (Figure 2). The topography was developed in the clearcut area on the south-east side of Carbon Creek. No survey was carried out on the north-west side of Carbon Creek. This topography was used for developing design layouts and was also used in the flood study to help determine predicted flood water elevations.

SECTION 3.0 - HYDROLOGY

3.1 FLOOD FREQUENCY ANALYSIS

As part of this preliminary design study, a flood frequency study was carried out by KPA Engineering Ltd for B.C. Hydro.[3] Carbon Creek is ungauged, but a number of gauging stations exist in neighbouring basins. A regional curve for the Carbon Creek Basin was developed for the 2-year flood based on the data available from neighbouring basins. The drainage basin which feeds Carbon Creek at the proposed spawning channel site has an area of approximately 242 km^2. From the regional curve for the 2-year flood, the Carbon Creek site is estimated to have a peak instantaneous discharge of 33.6 m^3/s.

A dimensionless frequency curve was also developed based on the neighbouring basin gauge data. This curve relates dimensionless flood quantity (normalized against the 2-year flood) to return period. From this curve the flood at any period can be determined for Carbon Creek by multiplying the 2-year flood by the dimensionless multiplier associated with a given return period. For example, a multiplier of 1.75 is used for a 10-year flood. Therefore, the 10-year flood discharge at the Carbon Creek site is 1.75 x (33.6 m^3/s), which equals 58.8 m^3/s (Figure 3).

3.2 DESIGN FLOOD

KPA developed a relationship between flood return period, instantaneous discharge, and water elevation (Table 1) at Section A-A (Figures 2 and 4). Floods which would overtop the banks of Carbon Creek, at Section A-A, are predicted to have a return period of two years. Since the floodplain is relatively wide compared to the depth of water, large fluctuations in flood discharge result in small changes in water elevation. For example, the 2-year flood instantaneous discharge is estimated to be 33.6 m^3/s, which corresponds to a water elevation of 866.7 m. The 20-year discharge is estimated to be approximately 73.0 m^3/s, which corresponds to a water elevation of 867.4 m. The discharge more than doubles from the 2-year to 20-year flood, but the water level only rises by approximately 0.7 m.

The banks of the side channels (Channels A and B, Figure 2) will not be overtopped until the Carbon Creek water level at Section A-A reaches an elevation of approximately 867.5 m, which corresponds to a flood return period of approximately 20 years.

Since the water levels only increase moderately with large increases in discharge flows, there is only a small incremental cost associated with protecting the side channel against a large flood. For example, at Section A-A, the 100-year flood would produce a water elevation of 867.7 m and the 20-year flood would produce a water level of 867.4 m. Therefore a protective berm would only need to be raised 0.3 m to increase the flood protection from 20 years to 100 years. Material excavated from the spawning channel can be used as berm construction material. Therefore, to provide added protection at minimal additional cost, it is recommended to protect the spawning channel against the 100 year flood.

SECTION 4.0 - SPAWNING/REARING CHANNEL

4.1 TARGET FISH SPECIES

Several freshwater fish species may use the spawning/rearing channels. Spawning habitat in the main river is very restricted and rearing habitat for young of the year is less than ideal. The primary target species for these channels are kokanee (introduced) and rainbow trout (native and introduced). Native bull trout may also benefit from the channels but utilization of this type of habitat is unknown. There is also the possibility, in the future, of re-introducing Arctic grayling back into this system via the side channels.

There are ongoing efforts by the PWFWCP to establish a self sustaining population of kokanee in Carbon Creek. Kokanee have been released into the existing side channel in anticipation of the project and stocking will continue after the completion of the channel.

Kokanee and bull trout typically spawn in September and October. The kokanee fry will hatch the following spring and immediately move downstream to the Williston Reservoir. Rainbow trout and Arctic grayling spawn in April and May, with the young hatching in early to mid summer. Both these species plus bull trout require stream rearing habitat, which the side channels will be designed to provide. Newly hatched Arctic grayling fry are extremely susceptible to mortalities caused by high flows. The side channels will provide rearing habitat that is not subject to high flows. The channel may also provide additional over wintering and rearing habitat for older juvenile and mature fish.

The following general habitat criteria have been supplied by Brian Blackman:

Riffle to pool ratio : 10:1

- Pool depth : 0.9 to 1.1 m
- Riffle water velocity : 0.2 to 0.5 m/s
- Gravel Size : 50 mm minus with a maximum of 5% passing the #200 sieve size (silt size).
- Gravel thickness : 30 cm
- Dissolved Oxygen Content: Greater than 6 mg/l

4.2 EXISTING CHANNEL CONDITIONS

Several inspections of the Carbon Creek side channel site have been conducted since 1991. A summary of the data collected during this period is as follows:

Photographs taken in July and October 1991 show significant flow in the existing side channels. Both riffles and pools are evident in the photos. The flow was partially constricted by debris jams from previous flood events, logging debris, and beaver dams.

A topographic survey of the side channels was carried out on 28 May 1992. The elevation along the thalwegs of Channels A and B was determined, as well as the water depth, and channel width. The survey was only carried out in the clear cut portion of the channel alignments. Water depths ranging from 10 cm at riffle locations to approximately 100 cm at pool locations were measured. Channel flow rates were also measured in Channel A (downstream of the confluence with Channel B), and in Channel B. A flow of 720 litres/second (l/s) was measured in Channel A, and a flow of 120 l/s was measured in Channel B.

During the September 1994 feasibility study, Channel B was dry and the flow in Channel A was largely reduced to isolated pools. The feasibility study was carried out during the summer low water levels. Test pits excavated in the upper reaches of the channels exposed the groundwater- approximately 0.5 m below the ground surface. Pump tests carried out in the test pits indicated that the coarse fluvial sediments are free draining and significant groundwater could be captured by an opened channel, even during this relatively dry season.

A site inspection was carried out on 13 March 1995 by Brian Blackman.[5] The inspection included a general reconnaissance of the site, side channel oxygen content readings, water temperature measurements, and estimates of flow quantities.

During the 13 March 1995 site inspection the air temperature was approximately 5°C, unseasonably warm for this time of year. The air temperature for the preceding 2 weeks had been normal. Temperatures, measured at the Bennett Dam, ranged from -4°C to -25°C during the period 1 March to 12 March 1995. Temperatures were warmer on 12 and 13 March, ranging between -7 and 2°C. There was a 1 to 1.5 m snow pack at the site.

On 13 March 1995, the main Carbon Creek channel and the two side channels were frozen over for most of their length. A 280 m long section of Channel A was open (Sta. 9+40 to 12+20). There was also a 210 m length of the Carbon Creek main channel open at the north-east end of the clear cut. The open section of Carbon Creek was directly adjacent to the open section of Channel A. This open water, with temperatures well above freezing, may indicate a strong groundwater upwelling area.

Detailed inspection was carried out at 4 sites during the 13 March 1995 Inspection. A summary of the 4 sites is as follows:

Site 1: Channel A - Approx Sta. 11 +20

Water Temperature : 5.4°C

Oxygen Content: 6.4 mg/l (parts per million)

Water Flow : Approx 15 to 60 l/s

Open Water

Site 2: Channel A - Approx Sta. 9+50

Water Temperature: 2.3°C

Oxygen Content: 3.5 mg/l

Open Water

Site 3: Channel A-Approx Sta. 0+30

Water Temperature: 0.8°C

Oxygen Content: 11.3 mg/l

The oxygen content was likely influenced by disturbance and aeration caused by the ice auger.

The channel at this site was frozen, with approximately 25 cm of layered ice and water overlaying approximately 5 cm of water at the floor of the channel.

Site 4: Channel B - Approx Sta. 100+20

Water Temperature : 1.1 °C

No oxygen content measured.

This site was located at a 1994 test pit. The test pit was frozen to the bottom. A hole drilled through the ice to the bottom of the pit immediately filled with water to a depth of approximately 30 cm. (Water surface elevation approximately 866 m).

4.3 GROUNDWATER FLOW

The groundwater in the area of the side channel generally flows along the floodplain and the groundwater surface is generally less than 2 m below the ground surface. The groundwater wells up to the surface along parts of the side channels and the main Carbon Creek channel. The groundwater is recharged from the floodplain upstream, as well as the valley slopes.

In the area of the side channels, the Carbon Creek floodplain is approximately 300 m wide, and has a gradient of approximately 0.5%. Elevations of ponds and water levels in test pits indicate that the water table is at or near the ground surface, and has a gradient approximately parallel to the floodplain ground surface. Winter water temperatures measured in ponded water along the side channel indicate that the groundwater flowing along the floodplain will likely remain warm enough to prevent the channel water from completely freezing. Temperatures measured between 1 December 1993 and 31 March 1994 ranged from a low of 0.4°C to a high of 2.7°C.

Water flows down the valley slopes in surficial streams as well as subsurface flows. Two small springs and one small creek flow from the south valley slopes, pass through culverts under the logging road, and enter Channel A. The flows from these springs and creek totalled approximately 70 l/min during the September 1994 site visit. The soil veneering the bedrock valley walls is colluvium overlying glacial till. The glacial till likely has a permeability several orders of magnitude less than the fluvial sediments found on the valley floor. Therefore, springs and creeks flowing down the valley slopes are likely a significant source of groundwater recharge during the spring, summer, and, fall. During the winter months when surface streams and springs are frozen, there may not be significant recharge from these slopes.

During the September 1994 test pit program, the groundwater in the area of the side channel was found to be approximately 0.5 to 1 m higher than the water levels measured in the Carbon Creek, adjacent to the test pit locations. It is likely that the water level in the floodplain is generally higher than the creek water level throughout most of the year. In other words, the creek is recharged by the floodplain groundwater. If a groundwater fed side channel is developed adjacent to the creek, it is possible that the groundwater would be drawn down to a point where the seepage flow would be reversed, and the side channel would be recharged by water seeping from the main Carbon Creek.

4.4 SPAWNING CHANNEL LAYOUT

It is proposed that the top 300 m of Channel A (Sta. 0+50 to 3+50) and a 400 m length of Channel B (Sta. 100+70 to 104+70) be developed as groundwater fed spawning habitat (Figure 2). The development of the upper portion of the side channels as spawning habitat is considered to be optimal for the following reasons:

- The amount of habitat available for spawning and rearing is maximized by using the entire length of the side channels.

- Having the spawning habitat upstream of the rearing habitat is generally favourable, allowing the fry to swim downstream to the rearing habitat once they have hatched.

- Since there is potential for the side channel to be inundated with flood water, it is proposed to protect the spawning habitat with a berm. By developing the upper reach of the channel as spawning habitat, the length of berm required to protect the spawning habitat, without cutting off part of the side channel, is minimized. Section 4.7 presents details of the flood protection berm.

  A creek flowing down the south valley slope enters Channel A downstream of the proposed spawning habitat. Therefore, if there is any silt load carried by the creek, it will not threaten the spawning habitat.

To insure adequate groundwater flow into the side channels, the channel floor should be excavated to a depth approximately 1 m below the minimum groundwater level. To date, the minimum groundwater levels measured at the site were measured during the March 1995

Investigation. During the March 1995 investigation, a water level in test pit 3 (excavated during the September 1994 investigation) was measured. The water level measured in March 1995 was approximately 0.3 m lower than the level measured in September 1994. Therefore, it was assumed that the minimum winter groundwater levels are approximately 0.5 to 1 m lower than those measured in September 1994.

It is important to insure that the spawning channel is excavated well below the winter groundwater level to insure that the incubating eggs will not freeze. In order to excavate the channels to a depth 1 m lower than the annual low water table, the channel floor would need to be lowered by approximately 1 to 2 m. The overburden in the area of the upper reach of the channel consists of 0 to 1 m of organic fine grained soil overlying a coarse mixture of sand, gravel, cobbles, and boulders.

It is proposed to excavate the floor of Channel A, to an elevation ranging from 864.0 m at Sta. 0+50 to 863.5 m at Sta. 3+50. The spawning channel will be excavated at a relatively smooth gradient. Pools will be excavated at a spacing of approximately 60 m to provide spawners protection from predators. The channel floor will be excavated to a width of approximately 4 to 6 m, with the banks excavated at a slope of 1.5 horizontal to 1 vertical (Figure 4).

It is proposed to excavate the floor of Channel B, to an elevation ranging from 865.0 m at Sta. 100+70 to 864.0 m at Sta. 104+70. The floor of Channel B will be excavated to a width of approximately 2 m and the channel banks will have a slope of 1.5 horizontal to 1 vertical (Figure 4).

Following the channel excavation, the gradation of the native gravel forming the floor of Channel A can be evaluated. If the gravel is deemed unsatisfactory for spawning habitat, the excavated material can be screened, and the appropriate spawning gravel gradation can be replaced into the channel. If there is not sufficient quantities of spawning gravel at the site, the channel could be lined with imported spawning gravel. The spawning gravel must be well graded, well rounded, clean, coarse sand to coarse gravel. The gravel must have less than 5% fines (< #200 sieve), and be a mixture of coarse sand and gravel, with maximum grain size of 50 mm.

It is not intended to line Channel B with gravel during the initial construction project. Channel B is primarily intended to supply water for Channel A. If significant fish populations are developed in Channel A, and more habitat is required, spawning gravel could be added to Channel B at a later date.

4.5 GROUNDWATER SEEPAGE

The winter groundwater seepage into the developed upstream portions of Channels A and B was modelled using the finite element program SEEP-W. The input parameters, which included site geometry, groundwater elevations at the recharge boundaries, and soil permeabilities, were estimated based on the limited data collected at the site. A sensitivity analysis was conducted to determine a range of groundwater seepage flows that could be expected in the developed channels. The analysis is most sensitive to the input permeability. Based on the qualitative information obtained during the 1994 test pit program (soil description and pump test flow rates), the permeability of the coarse gravel and cobble unit was estimated. Typically for a mixture of gravels and cobbles, permeabilities range from 10^{-2} to 10^{-3} m/s.

Table 2 summarizes the computed winter groundwater seepage flows into Channel A and B for gravel and cobble permeabilities of 10^{-2} and 10^{-3} m/s. The total winter flow rate at the downstream end of the spawning channel (Sta. 3+50) is estimated to range from 40 to 400 l/s. The seepage flow into the channel per lineal m is estimated to range from 0.01 l/s to 0.9 l/s.

The seepage model was intended to simulate the winter low water level. In this model, groundwater recharge from the south valley slopes and surface water flow into the channel was assumed to be negligible. The sources of recharge used in the model were lateral seepage from Carbon Creek and groundwater flow from the upstream floodplain (Figures 5 and 6).

There may be winter flow from the south valley slope, but no permeability or groundwater data are available for the rock and soil in this area. It is assumed that the soil and bedrock comprising the south slope have permeabilities much lower than the valley floor fluvial deposits. Therefore the winter recharge from this source was considered to be negligible.

4.6 REARING HABITAT LAYOUT

The lower 920 m of Channel A (Sta. 3+50 to 12+70) is proposed to be developed primarily as rearing habitat. The rearing channel would be used by rainbow trout and possibly Arctic grayling and bull trout. The lower reach of Channel A has been inspected in the winter, spring, summer, and fall. The channel in its present status remains wetted throughout most of the year with significant pool depths and riffle flows. In general this section of the channel provides excellent habitat, therefore significant improvement to the lower reach of Channel A is not required.

The construction along the lower reach of Channel A will consist primarily of clearing debris and developing a riffle-pool habitat. The proposed riffle length to pool length ratio is approximately 10 to 1. Some spawning gravel placement is proposed along the length of the rearing channel. A profile of the rearing channel excavation is presented on Figure 4. Some large woody debris will be left in the channel as cover for the juvenile fish. The construction of the rearing habitat (Sta. 3+50 to 12+70) will be modified in the field as required. The profiles of Channel A, as shown on Figure 4, are intended to be used for estimating purposes. Approximately 500 m^3 of material will be excavated from the rearing habitat, and approximately 400 m^3 of spawning gravel will be replaced.

The spawning gravel will be largely concentrated between Sta. 9+40 and Sta. 12+20. This length of channel was open during the March 1995 inspection, the oxygen contents were greater than 6 mg/l, and the temperatures were considerably warmer than in the remainder of the channel.

It is anticipated that most of the material excavated between Sta. 3+50 and Sta. 12+70 will be primarily coarse material. A thin layer of organics may need to be cleared prior to excavation of the coarse material.

No work, other than clearing debris from the side channel, is intended downstream of the tree line (downstream of Sta. 12+70). This debris will be cleared by hand.

4.7 FLOOD PROTECTION BERM

As described in Section 3.2, the overbank flood event at Carbon Creek has a return period of 2 years. At Section A-A the top of bank elevation is 866.74 m. The 100-year flood elevation is estimated to be 867.66 m at Section A-A. Since the 100-year flood only raises the water level to an elevation approximately 1 m above the top of bank, it is proposed to construct a setback berm along the north bank of the spawning channel to protect the developed spawning habitat. The berm will protect the upper 400 m of the spawning channel against direct flood inundation, and will also protect the upper 350 m of developed spawning channel from backflooding. The proposed berm is approximately 1 to 1.5 m high, 3 m wide at the crest, and 600 m long (Figures 2 and 4). The berm crest elevation is designed for the 1:100 year flood with a minimum freeboard of 1.0 m. Protection of the spawning habitat is desired since flood waters inundating the spawning gravels could cause siltation or erosion of the spawning gravels.

The berm would be constructed from the coarse material excavated from the spawning and rearing channels. Based on visual descriptions and photographs of the coarse material, the D_{50} is estimated to be approximately 100 mm. The water velocity during a flood event is estimated to be approximately 1 to 2 m/s. A D_{50} stone size of 100 mm is appropriate for velocities of this magnitude.[2] It is proposed that the berm crest can be used as an access road for channel maintenance and improvements.

Channel A, downstream of Sta. 3+50, will not be protected by a berm. This length of channel will be primarily designated as rearing habitat, and therefore, it will not be as sensitive to flood inundation as the upstream spawning habitat. Flood events large enough to inundate the side channels are only expected once every 20 years, and the damage will likely be confined to some minor siltation and channel bank sloughing.

4.8 EXCAVATED MATERIAL SPOIL

During the construction of the spawning/rearing channel, approximately 6500 m^3 of gravel, cobbles and boulders, and 2100 m^3 of organic soil will be excavated from the channel.

It is proposed to first clear the organic material from the top of the channel. The organics will be spoiled adjacent to the channel banks. In the area where the protective berm will be

placed, the organics will be spoiled a minimum of 12 m back from the top of the channel bank. In areas where no berm will be placed the organics will be spoiled a minimum of 2 m back from the top of the channel bank. The organics will be spoiled in piles with a maximum thickness of 1 m.

The gravel, cobbles, and boulders excavated from the channel, will be screened for 50 mm minus material. Based on gradation estimates from field descriptions and photographs of the coarse material, approximately 30% of the material will have a diameter less than 50 mm. Therefore, approximately 2600 m^3 of the coarse material will need to be screened to obtain 800 m^3 of spawning gravel. The spawning gravel will be stockpiled, and later replaced in the channel. The remainder of the coarse material will be used to build the protective berm along the north side of Channel B and Channel A (downstream of the confluence with Channel B) (Figures 2 and 4).

SECTION 5.0 - MAINTENANCE OF THE SPAWNING/REARING CHANNELS

Maintenance of the spawning/rearing channel will include annual clearing of debris and possibly beaver dams. The upper spawning habitat will be protected from flood waters by the protective berm, therefore significant maintenance will likely not be required in the upper reach. The bulk of the maintenance work will be able to be done by hand.

SECTION 6.0 - COST ESTIMATE AND SCHEDULE

6.1 CONSTRUCTION COST ESTIMATE

A cost estimate was prepared for the construction of the spawning/rearing channel as described above.[4] Costs for two alternatives were estimated. Alternative 1 calls for the processing of spawning gravel at site by screening the excavated coarse material. Alternative 2 calls for importing the spawning gravel from a borrow pit located 20 km from the site. The estimated total direct construction cost for Alternative 1 is $76,900, and the estimated cost for Alternative 2 is $84,800. Management, engineering, insurance, and a 20% construction contingency add an additional $30,700 to the Alternative 1 cost and $32,400 to the Alternative 2 cost (Table 3).

The following major equipment was assumed for the cost estimates:

1 - D6H Cat Dozer
1 - 235D Cat Backhoe
1 - 966F Cat Loader
1 - RD40 Read Screen-all
5 - Highway Haul Units (w/ pups) (for Alternative 2 only)

Alternative 1 will require an estimated 700 person hours (construction workers) and Alternative 2 will require an estimated 775 person hours (construction workers). These estimated hours do not include B.C. Hydro supervision. Table 4 and 5 show detailed cost break downs for the Alternative 1 and 2 construction.

Cost allowance has been provided in the estimate for environmental items including:

- Seeding and tree planting in disturbed areas and along channel banks.
- Silt control using diversion channels and settling ponds.
- Oil containment and cleanup absorbent sheets.

6.2 CONSTRUCTION SCHEDULE

The construction, which would be scheduled for August-September, is estimated to take approximately 4 to 5 weeks (Figure 7).

SECTION 7.0 - CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

1. Results of the feasibility study and groundwater seepage analyses carried out during this preliminary design phase indicate that a significant amount of groundwater seepage flow could be captured by a developed side channel of Carbon Creek.

2. Flood frequency studies indicate that overbank flood events will occur in the study area of Carbon Creek with a return period of approximately 2 years. Although overbank flood events are common, the water elevations and velocities are low, and minimal work is required to protect the channel.

3. It is proposed to develop the upper reach of the side channel as spawning habitat and the downstream portion of the channel will be primarily developed as rearing habitat, with small pockets of spawning gravel.

4. It is proposed to screen the coarse material excavated during the construction of the spawning/rearing channel, and replace appropriate sized spawning gravel into the channel. If it is determined that the local gravel is not appropriate, imported material may be required.

5. A protective berm approximately 1 to 1.5 m high by 3 m wide by 600 m long is proposed to protect the spawning channel from flood inundation. Flood inundation of the spawning gravel could lead to siltation or scour.

6. The spawning/rearing channel direct construction cost would be approximately $76,900 for the full development of the spawning/rearing habitat, as described in Section 4.0, if appropriate spawning gravel can be screened from the local material. If spawning gravel must be imported from borrow pits, located approximately 20 km from the site, the cost would increase to approximately $84,800. It is possible to develop only portions of the channel, and part of the construction could be deferred.

7.2 RECOMMENDATIONS

1. A site visit by a representative from the Soil Mechanics Department to confirm the source for the spawning gravel is recommended. The site visit should be made in the spring once the snow has melted.

2. Proceed with obtaining regulatory and corporate approvals for implementation of the project with a target construction period in August-September 1995. The August-September period is critical since dry weather will significantly improve construction conditions.

3. The construction of the channel could be carried out in several phases. The entire channel could be constructed in 1 year or part of the channel could be constructed in an initial phase, and additional construction could be carried out in future years if additional habitat or channel modifications are required.

   It is recommended that the entire channel excavation should be completed in the first construction season, the berm should be constructed, and spawning gravel should be placed in the channel between Sta. 2+00 and 3+50 and in selected regions between Sta. 3+00 and 12+70, with the majority of the gravel placed between Sta. 9+40 and 12+20. Approximately 400 m^3 of spawning gravel will be required to line these sections of the channel. An additional 400 m^3 of spawning gravel should be screened and stockpiled at the site for future placement.

4. Following the initial construction, the condition of the channel and the use of the habitat should be monitored. In specific the channel should be inspected during the following periods:

   - September-October (kokanee/bull trout spawning)
   - late winter (egg incubation)
   - April-June (rainbow trout/Arctic grayling spawning)

   Water temperatures, flows, depths, and oxygen contents should be monitored during these critical periods.

Once fish behaviour have been established, modifications to the channel can be made as required.

REFERENCES

1. Foy, M. et al, "Coho Salmon Enhancement in B.C. - Using Improved Groundwater Fed Side Channels", April 1990.

2. Richmond, Gary, "Feasibility of Groundwater Fed Artificial Spawning Channel at Carbon Creek", Diary - 27 September 1994.

3. KPA Engineering Ltd for B.C. Hydro, "Carbon Creek Spawning Channel - Flood Frequency Study", 16 February 1995.

4. Memo from J.M. Boots to M.R. Morgan, "Carbon Creek Spawning/Rearing Channel Cost Estimate for Channel Construction", 15 March 1995.

5. Blackman, Brian, "Carbon Creek Side Channel", Diary - 13 March 1995.

TABLE 1

WATER LEVEL VERSUS RETURN PERIODS
(SECTION A - A)

	Return period (years)							
	2	3	4	5	10	20	50	100
Instantaneous Discharge (m^3/s)	33.6	38.1	42.6	47.1	58.7	73.0	94.6	114.8
Elevation (meters)	866.74	866.88	866.95	867.14	867.25	867.38	867.55	867.66

TABLE 2
Estimated Winter Seepage Flows into the Spawning Channel
Based on SEEP-W Seepage Analysis

Location (Stations)	Flow/lineal m. ($k = 10^{-2} m/s$)	Flow/lineal m. ($k = 10^{-3} m/s$)
Channel A (0+50 to 2+30)	0.1 litre/sec	0.01 litre/sec
Channel A (2+30 to 3+50)	0.9 litre/sec	0.09 litre/sec
Channel B (100+70 to 104+70)	0.7 litre/sec	0.07 litre/sec

Total Flow ($k = 10^{-2}$ m/s) : . 1 (180) + .9 (120) + . 7 (400) = 400 I/sec
($k = 10^{-3}$ m/s) : .01(180) + .09(120) +.07 (400) = 40 I/sec

TABLE 3

CONSTRUCTION COST ESTIMATE SUMMARY

Project: CARBON CREEK-SPAWNING/REARING CHANNEL
Status: CAR estimate
Date: 13-Mar-95

	ALTERNATIVE 1 On-site screening Oct 94 $ Thousands	ALTERNATIVE 2 Off-site screening Oct 94 $ Thousands
CONSTRUCTION COST	76.9	84.8
DIRECT CONSTRUCTION COSTS	76.9	84.8
CONTINGENCIES	15.4	17.0
MANAGEMENT AND ENGINEERING	14.4	14.4
BCH INSURANCE AND BONDS	0.9	1.0
INDIRECT CONSTRUCTION COSTS	30.7	32.4
TOTAL CONSTRUCTION COSTS	107.6	117.2

NOTES:
(1) The total construction costs do not include corporate overhead, interest during construction, and inflation.
(2) Contingencies are 20 % of the direct construction cost and are intended to account for unforseen construction cost overruns.
(3) Management and Engineering includes costs for contract preparation, drafting, and part time site inspection by an engineer.

TABLE 4

CONSTRUCTION COST ESTIMATE (ALTERNATIVE 1)

COST ESTIMATE
($ October 1994)

ITEM	DESCRIPTION	QUANTITY	UNIT	DIRECT UNIT PRICE	DIRECT COST	INDIRECT COST	MARGIN	UNIT PRICE	TOTAL COST
	CHANNEL WORKS								
A1	MOBILIZE	1	LS	5,000.00	5,000.00	1,048.48	786.30	6,834.78	6,834.78
A2	PREPARE ACCESS TRAIL	1200	M	1.13	1,356.00	284.35	213.25	1.54	1,853.59
A3	CLEAR CHANNEL DEBRIS	400	M3	4.76	1,904.00	399.26	299.42	6.51	2,602.68
A4	EXCAVATE AND SPOIL ORGANICS	2100	M3	2.36	4,956.00	1,039.25	779.38	3.23	6,774.63
A5	EXCAVATE GRAVEL AND COBBLES	6500	M3	1.92	12,480.00	2,617.00	1,962.61	2.62	17,059.61
A6	SCREEN AND STOCKPILE GRAVEL	800	M3	16.41	13,128.00	2,752.89	2,064.52	22.43	17,945.40
A7	CONSTRUCT GRANULAR BERM	5700	M3	1.00	5,700.00	1,195.27	896.38	1.37	7,791.65
A8	PLACE SPAWNING GRAVEL	800	M3	3.01	2,408.00	504.95	378.68	4.11	3,291.63
A9	HYDROSEEDING/TREE PLANTING	7000	M2	0.62	4,340.00	910.09	682.51	0.85	5,932.59
A10	DEMOBILZE	1	LS	5,000.00	5,000.00	1,048.48	786.30	6,834.78	6,834.78
	TOTAL DIRECT COST				56,272.00	11,800.00	8,849.36		76,921.36

NOTE: The total costs above do not include any BCHydro contingency, management and engineering, corporate overhead, inflation and interest during construction.

TABLE 5

CONSTRUCTION COST ESTIMATE (ALTERNATIVE 2)

COST ESTIMATE
($ October 1994)

ITEM	DESCRIPTION	QUANTITY	UNIT	DIRECT UNIT PRICE	DIRECT COST	INDIRECT COST	MARGIN	UNIT PRICE	TOTAL COST
	CHANNEL WORKS								
A1	MOBILIZE	1	LS	5,650.00	5,650.00	1,054.44	871.58	7,576.01	7,576.01
A2	PREPARE ACCESS TRAIL	1200	M	1.13	1,356.00	253.07	209.18	1.52	1,818.24
A3	CLEAR CHANNEL DEBRIS	400	M3	4.76	1,904.00	355.34	293.71	6.38	2,553.05
A4	EXCAVATE AND SPOIL ORGANICS	2100	M3	2.36	4,956.00	924.92	764.52	3.16	6,645.44
A5	EXCAVATE GRAVEL AND COBBLES	6500	M3	1.92	12,480.00	2,329.09	1,925.18	2.57	16,734.28
A6	CONSTRUCT GRANULAR BERM	6500	M3	1.00	6,500.00	1,213.07	1,002.70	1.34	8,715.77
A7	IMPORT SPAWNING GRAVEL	800	M3	22.48	17,984.00	3,358.29	2,774.24	30.14	24,114.52
A8	PLACE SPAWNING GRAVEL	800	M3	3.01	2,408.00	449.40	371.46	4.04	3,228.86
A9	HYDROSEEDING/TREE PLANTING	7000	M2	0.62	4,340.00	809.96	669.49	0.83	5,819.45
A10	DEMOBILZE	1	LS	5,650.00	5,650.00	1,054.44	871.58	7,576.01	7,576.01
	TOTAL DIRECT COST				63,228.00	11,800.00	9,753.64		84,781.64

NOTE The total costs above do not include any BCHydro contingency,management and engineering,corporate overhead,inflation and interest during construction.

SCALE 1:250 000

CARBON CREEK SPAWNING/REARING CHANNEL

LOCATION PLAN

(FROM NTS 94-B &. 93-0)

FIG. 1

DWG NO 1006-C18-A49

NOTES:

1. FOR SECTIONS AND PROFILE SEE DWG. 1006-C18-D48
2. TOPOGRAPHY COMPILED BY KERR WOOD LEIDAL ASSOCIATES LTD. FROM AERIAL PHOTOGRAPHS FLOWN BY KENYON CONTRACTING CO. DATED NOV. 18 1994
3. SECTION E-E USED FOR SEEPAGE ANALYSIS.

0 50 100 150 200 METRES

ALL DIMENSIONS ARE IN METRES UNLESS OTHERWISE SHOWN

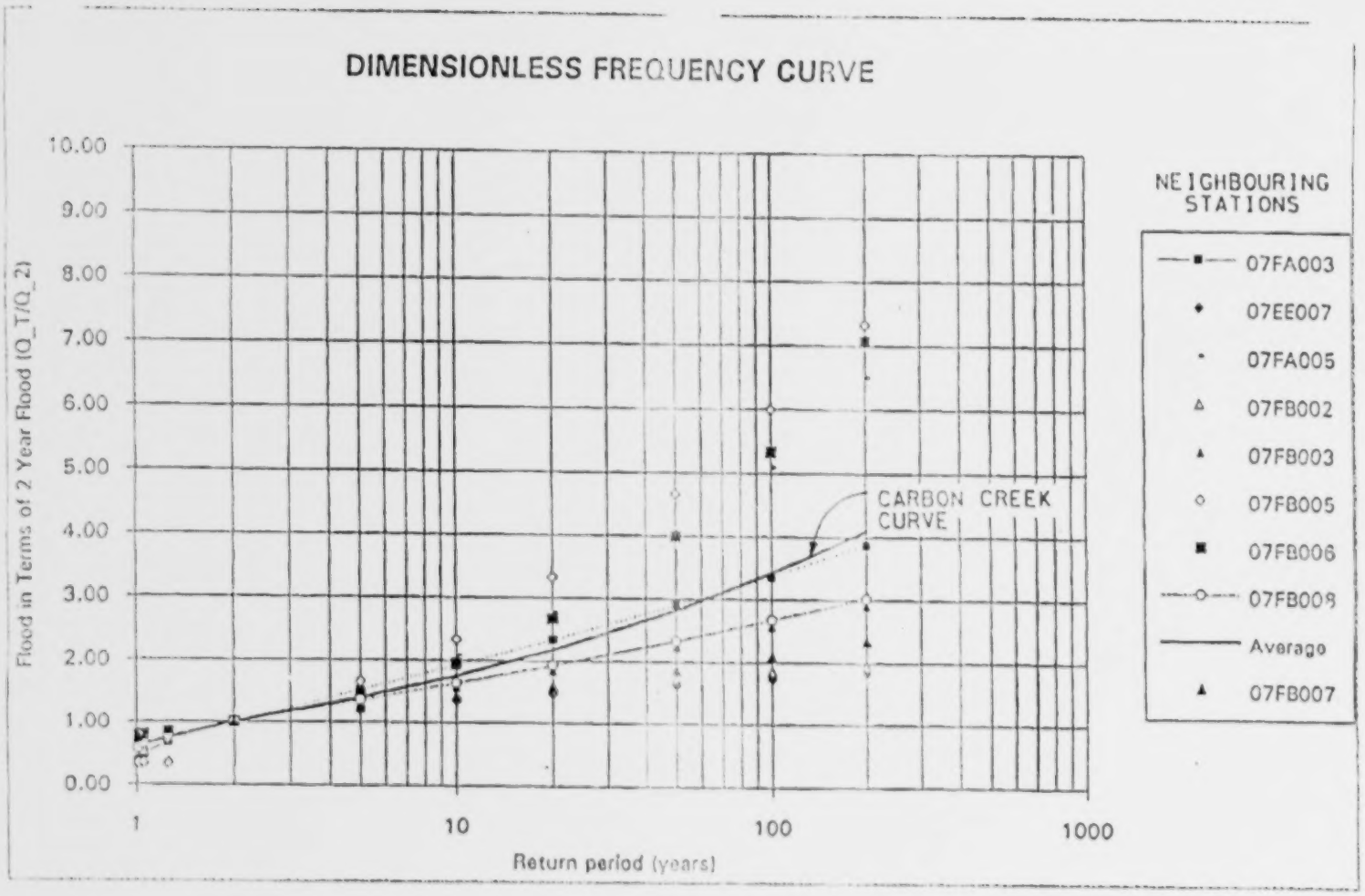
BCHydro

B.A.C. BENNETT DAM - RESERVOIR

CARBON CREEK SPAWNING/REARING CHANNEL
PLAN

FIG. 2

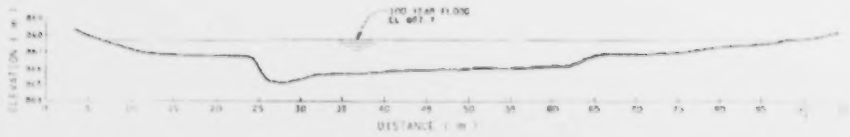
	19	as shown	1006-C18-D47	A



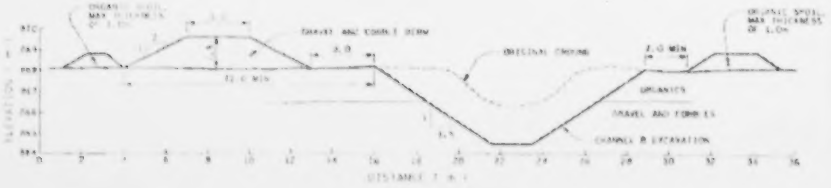
CARBON CREEK SPAWNING/REARING CHANNEL
DIMENSIONLESS FLOOD FREQUENCY CURVE
(FROM KPA REPORT, REFERENCE 3)

FIG. 3

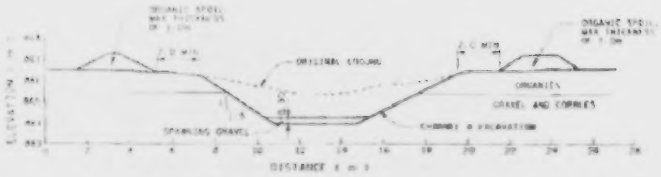
DWG NO. 1006-C18-A50



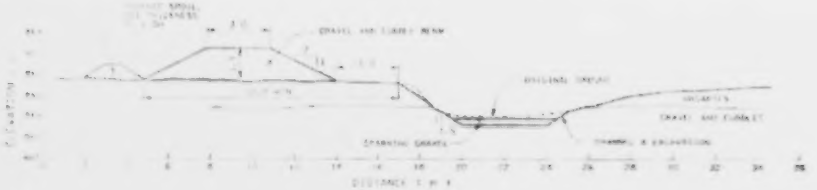
SECTION A-A



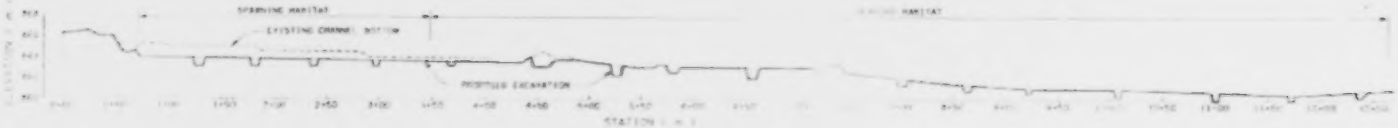
SECTION B-B



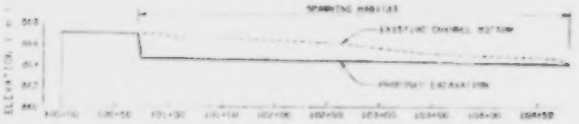
SECTION C-C



SECTION D-D



PROFILE ALONG ℄ OF CHANNEL A



PROFILE ALONG ℄ OF CHANNEL B

NOTES:

1. FOR PLAN AND LOCATION OF SECTIONS SEE DWG. 1006-C19-040

BC Hydro

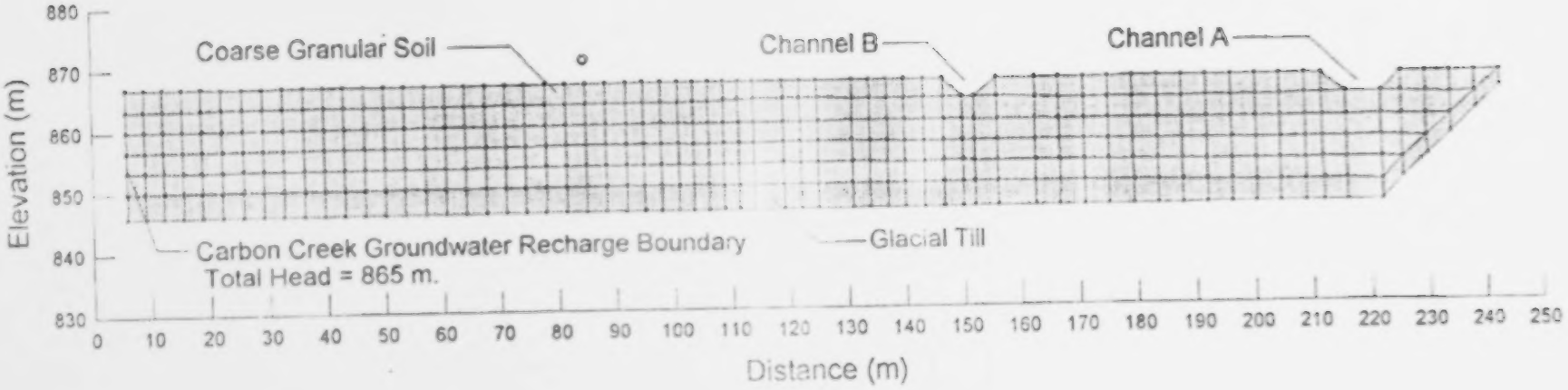
B.A.C. BENNETT DAM - ALTERNATIVE

CARBON CREEK SPAWNING/REARING CHANNEL
SECTIONS AND PROFILES

FIG. 4

1006-C19-040

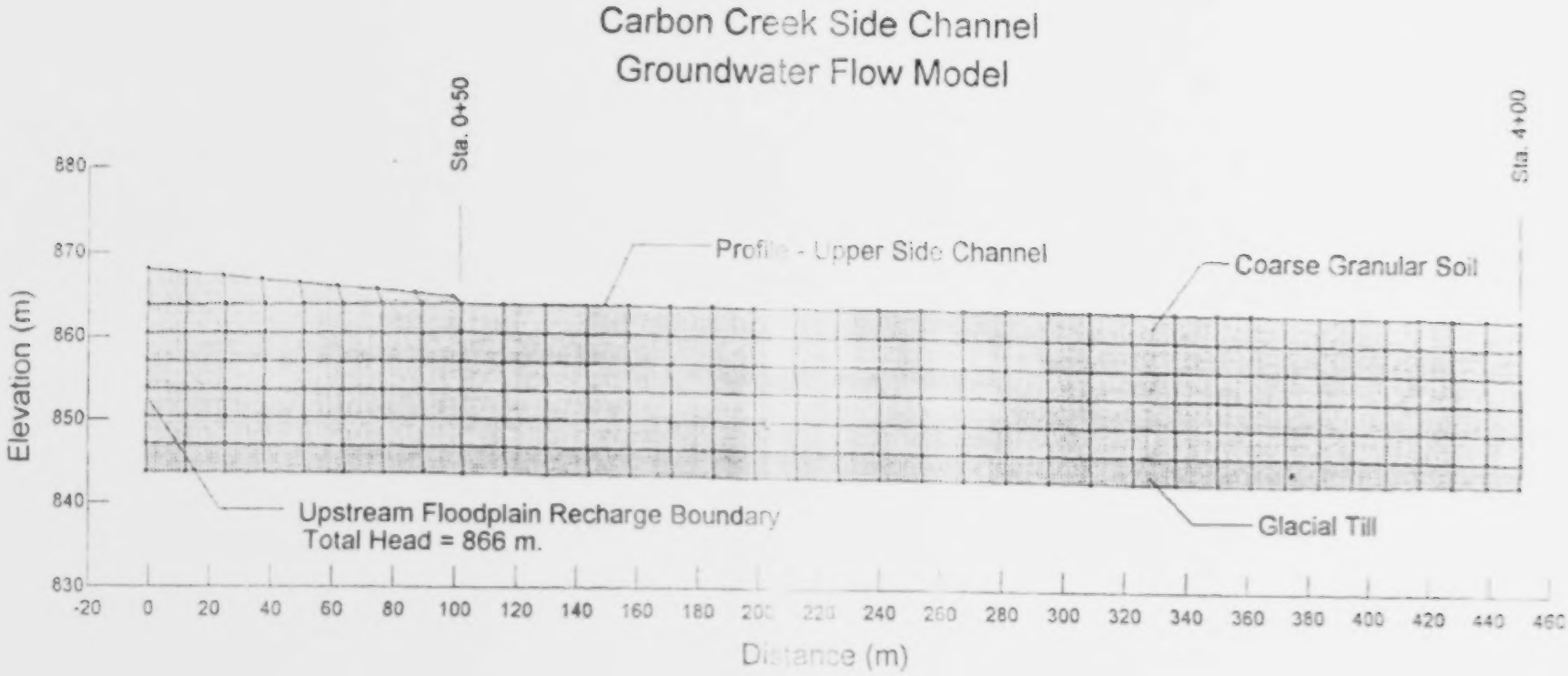
Carbon Creek Side Channel
Groundwater Flow Model



CARBON CREEK SPAWNING/REARING CHANNEL
SEEP-W SEEPAGE MODEL
CREEK RECHARGE
(SECTION E-E, FIG. 2)

FIG. 5

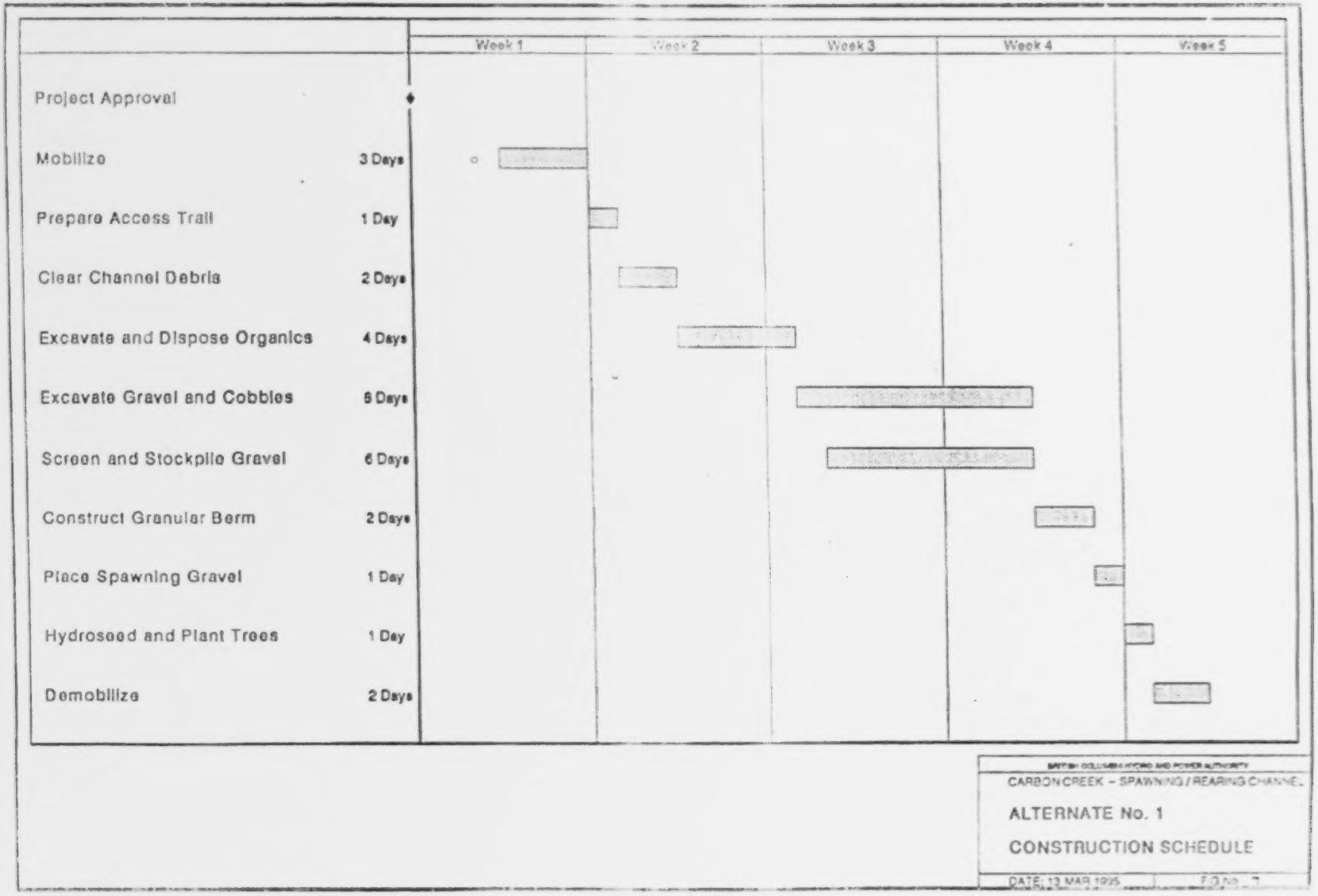
DWG NO. 1006-C18-A51



CARBON CREEK SPAWNING/REARING CHANNEL
SEEP-W SEEPAGE MODEL
UPSTREAM FLOODPLAIN RECHARGE

FIG. 6

DWG NO. 1006-C18-A52



SCHED1

REPORT No.